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(54) Energy management system

(57) The system includes a control computer which transmits control signals to a number of outstation control units, each associated with a particular location in a building or building complex. The control computer receives information such as external temperatures (from both north- and south-facing walls), maximum electrical demand information, weather forecast data and thermodynamic models of buildings. In addition to this, each outstation control unit includes air temperature and occupancy detectors for its associated location and subsequently controls operation of energy consuming devices such as heating and lighting systems in response to information received. Energy consumption information is also used by the control computer to provide maintenance management information such as time scales for work to be done, costs which have been incurred etc.

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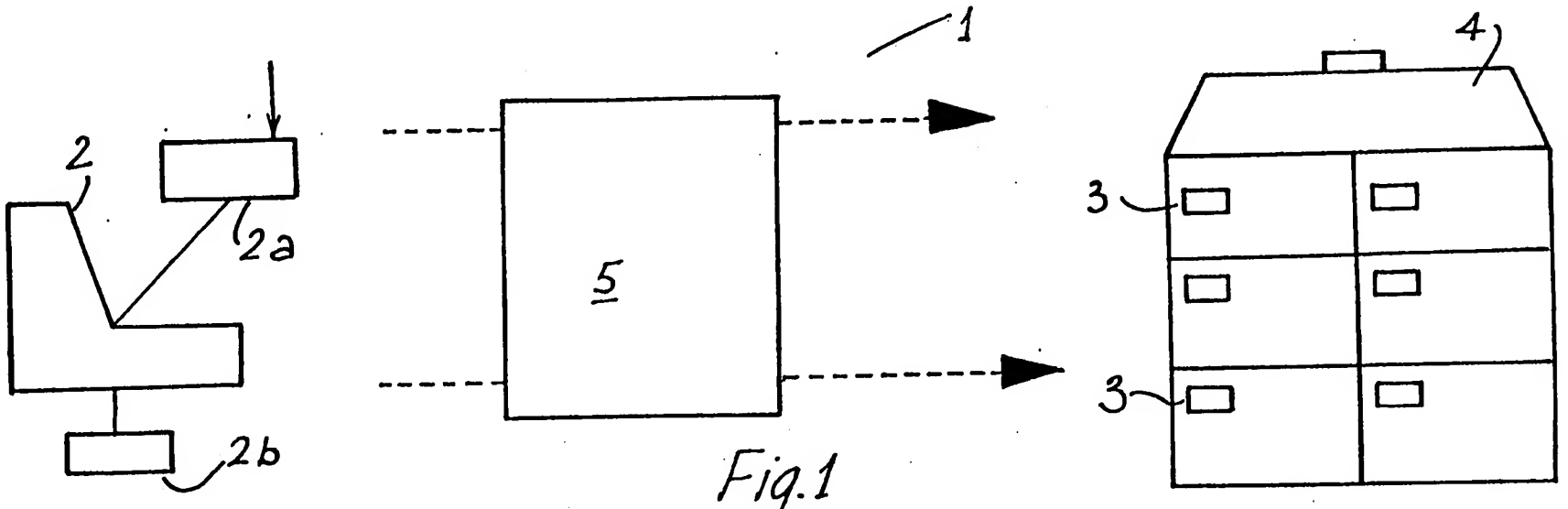

Fig.1

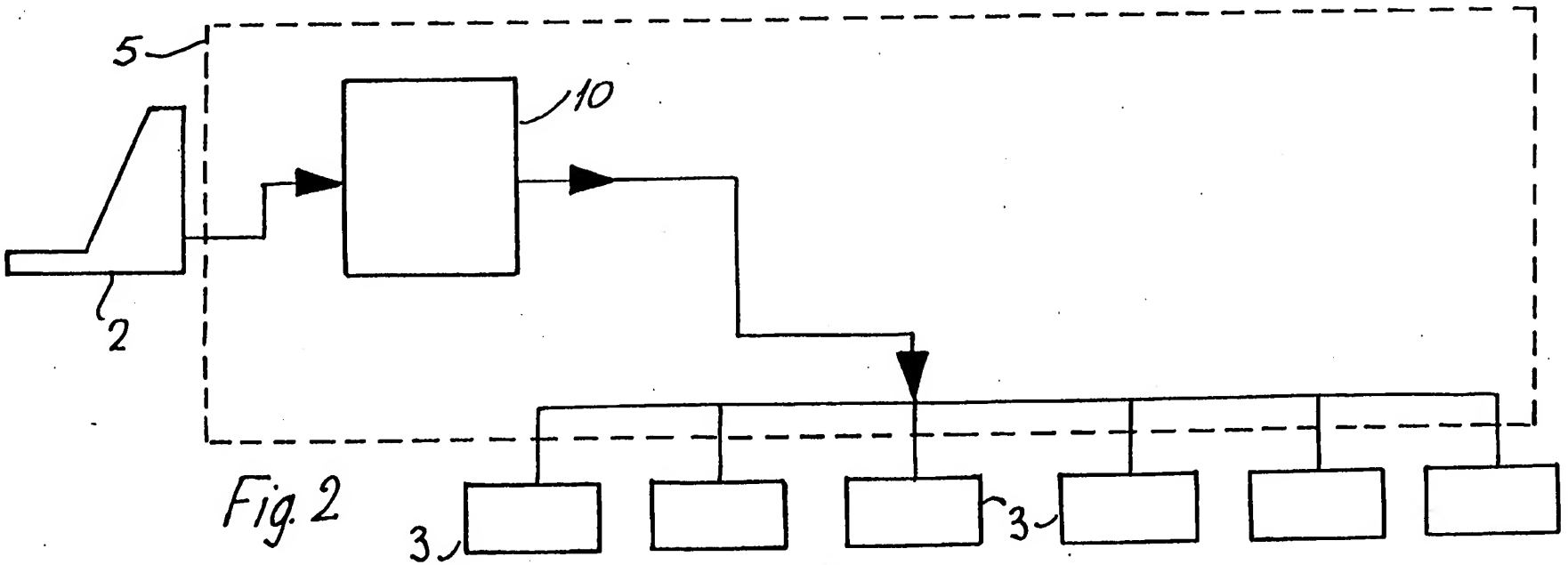

Fig. 2

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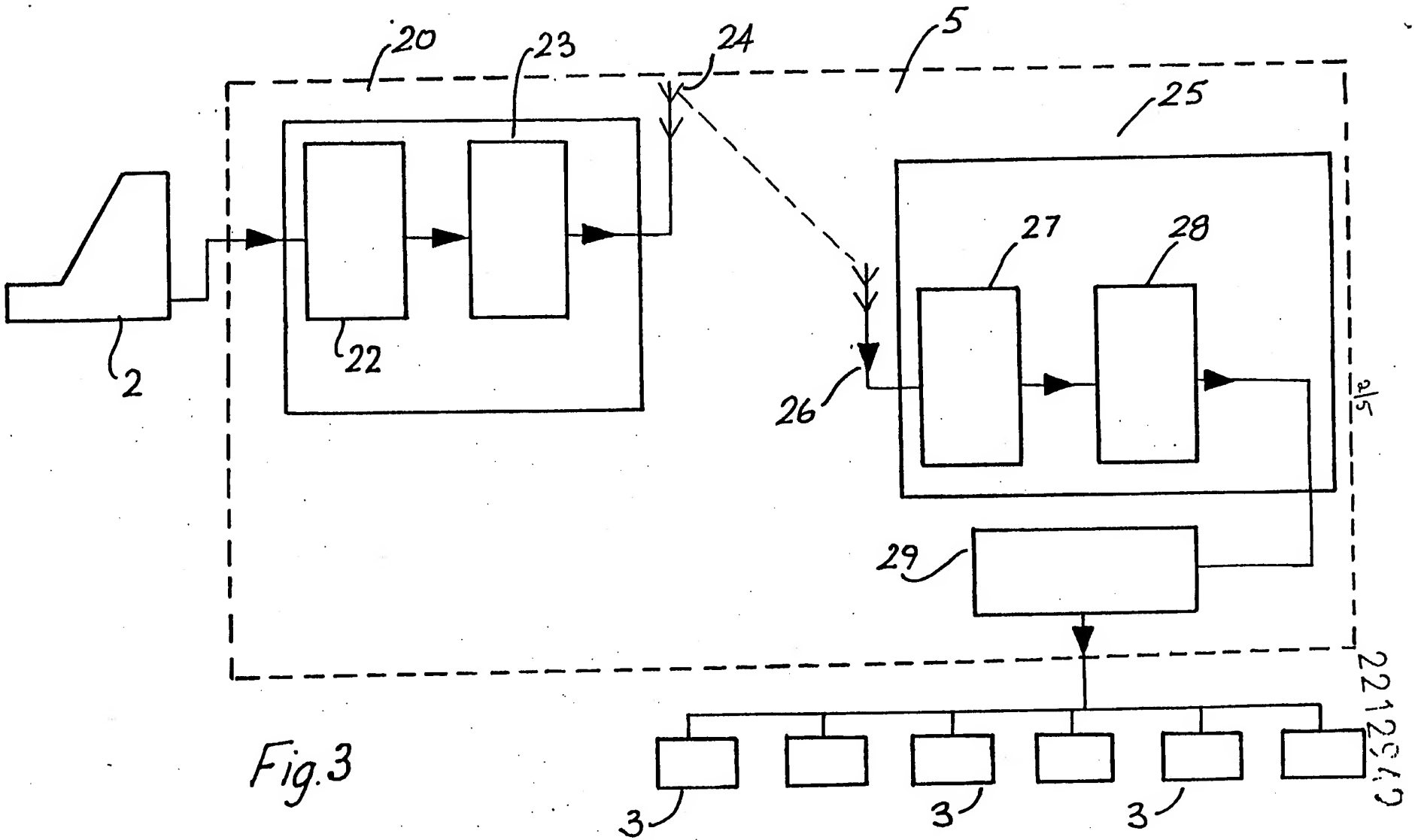

Fig.3

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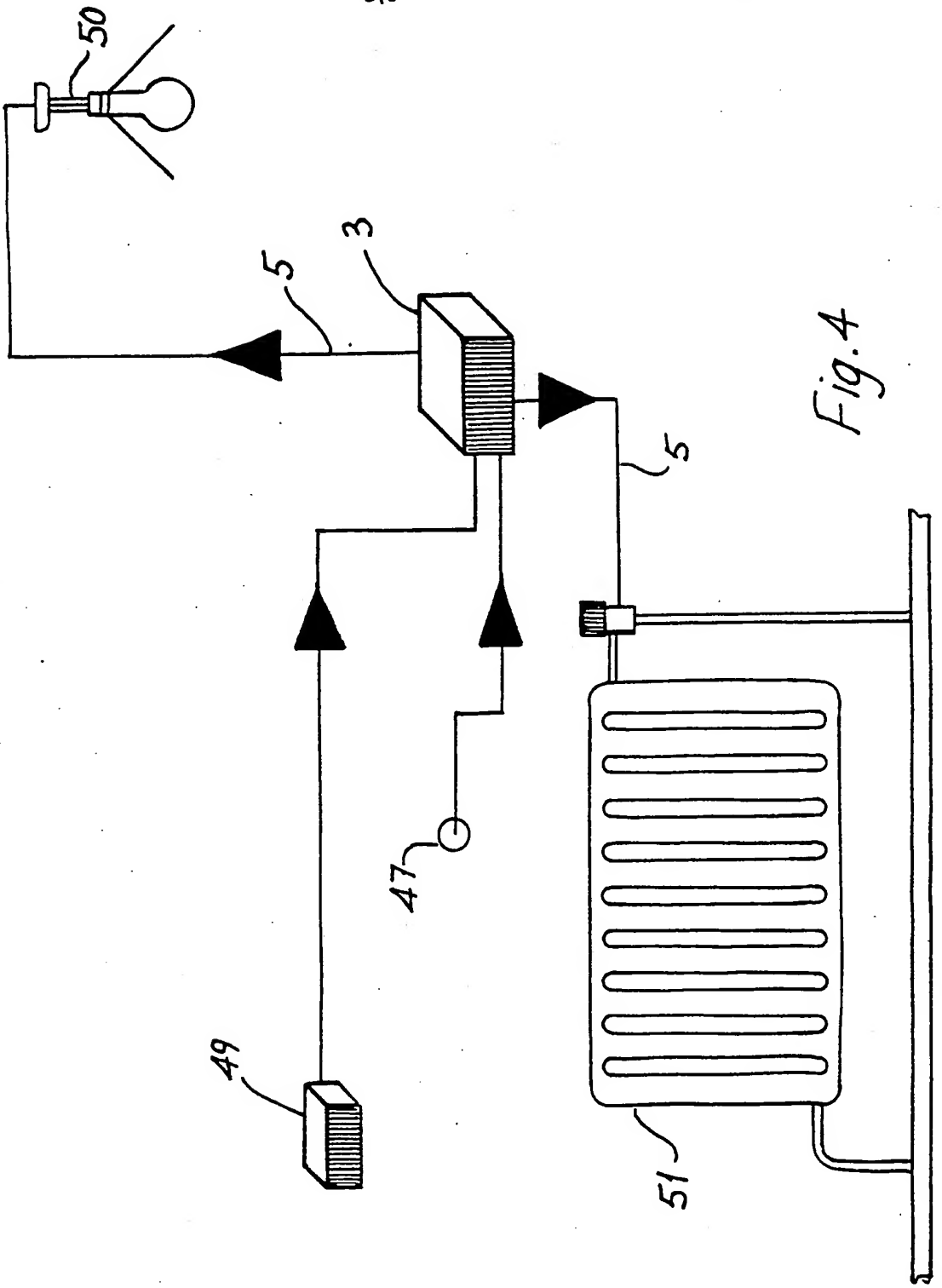

Fig.4

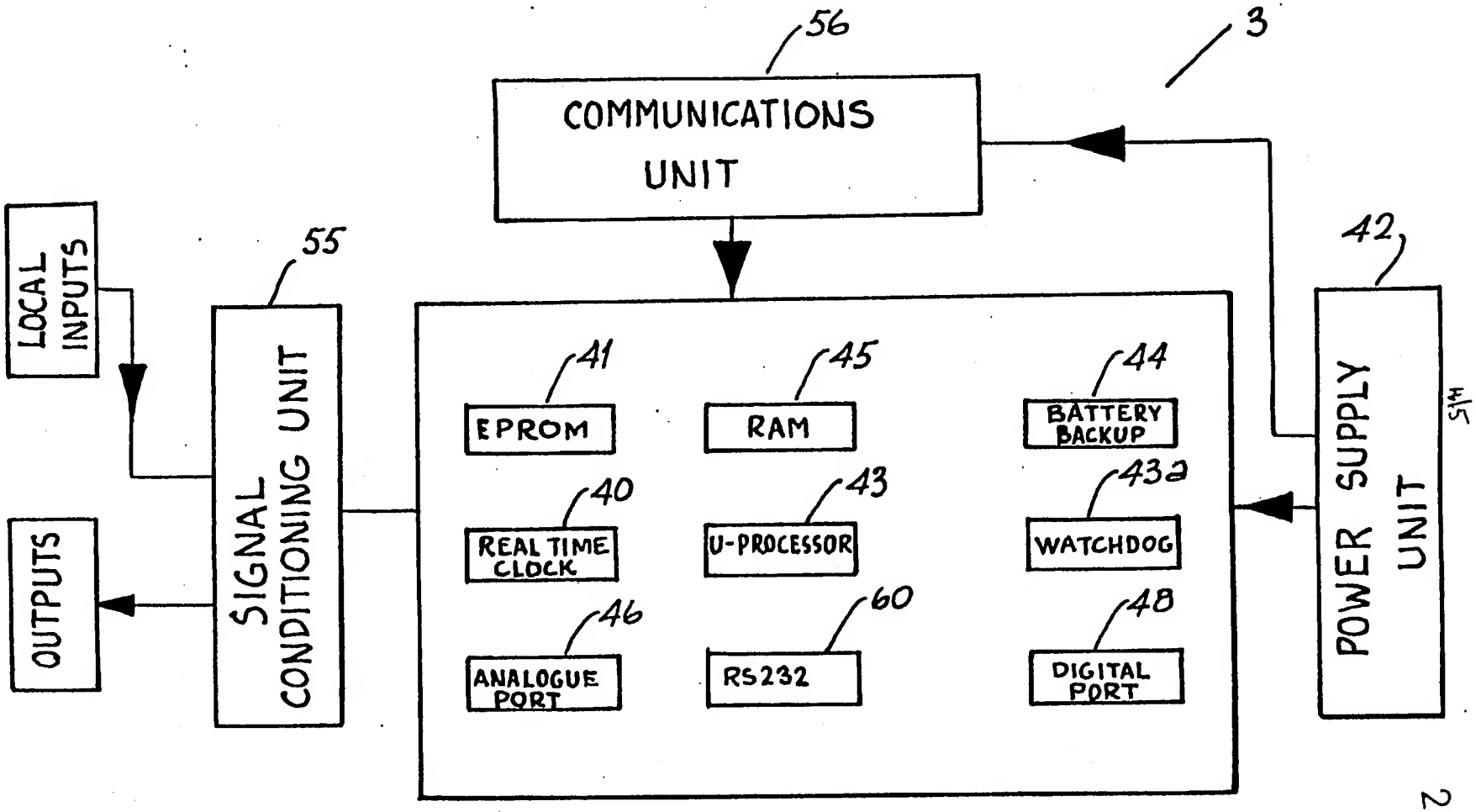
56
3
COMMUNICATIONS UNIT
LOCAL INPUTS
55
SIGNAL CONDITIONING UNIT
OUTPUTS
41
EPROM
45
RAM
44
BATTERY BACKUP
40
REAL TIME CLOCK
43
U-PROCESSOR
43a
WATCHDOG
46
ANALOGUE PORT
60
RS232
48
DIGITAL PORT
42
POWER SUPPLY UNIT

Fig. 5

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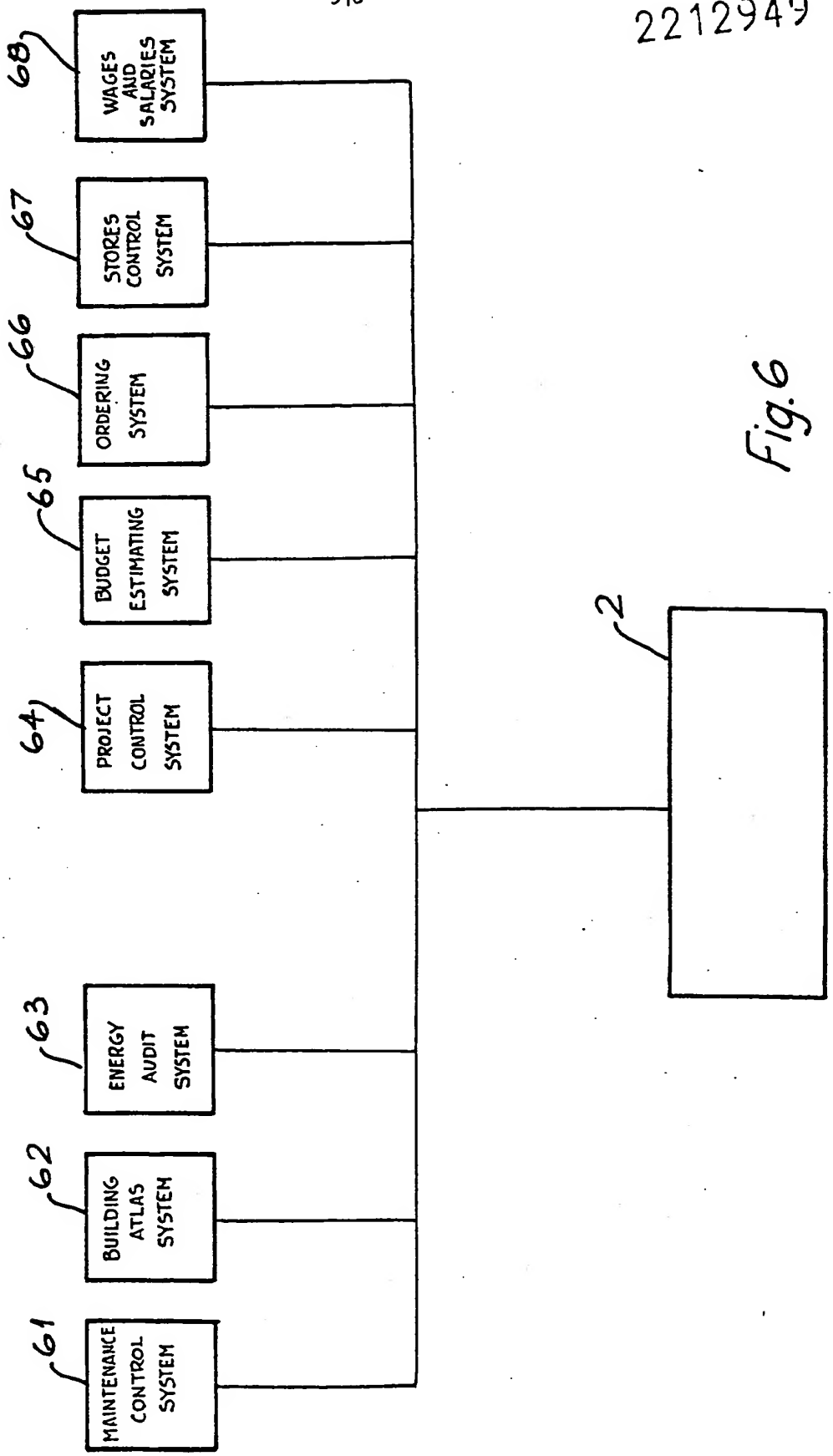

Fig.6

internal structures does not respond quickly enough. As a result, considerable amounts of energy are often wasted, for example, when large buildings are heated immediately after a cold spell.

Another problem with known energy management systems is that they do not monitor the operation of other energy-consuming devices such as lights. Further, they are generally inflexible in operation as they depend to a large extent on manually inputted parameters such as building occupancy times etc.

The present invention is directed towards providing an improved energy management system to overcome these problems.

According to the invention there is provided an energy management system for a building or building complex comprising a control computer, a plurality of outstation control units, each associated with a particular location in the building or building complex, and communication means for communication between the control computer and the outstation control units, wherein the control computer comprises input means for reception of general energy management information including external air temperatures outside both south-facing and north-facing building exterior walls, weather forecast data, and

building thermodynamic model data, processing means for processing the general energy management information and output means for subsequently transmitting control signals via the communication means to the outstation control units, and in which the outstation control units include means for controlling energy-consuming apparatus in their associated locations in response to the control signals transmitted from the control computer and to energy parameter sensors in their associated locations.

Ideally, the input means of the control computer comprises means for reception of maximum electrical demand information and means for processing this information to provide control signals for transmission to the outstation control units.

In one embodiment, the control computer further comprises means for reception of maintenance information including work to be done in each location, the processing means comprises means for providing maintenance management information based on the maintenance information and the duration of operation, of energy-consuming devices controlled by the outstation control units.

Preferably, the energy parameter sensors connected to the outstation control units include room occupancy detectors

and air temperature sensors.

In an ideal embodiment of the invention, the communication means includes a mains transmitter modem for transmitting control signals impressed on the mains power supply for the outstation control units.

Ideally, the communication means includes a radio transmitter and a radio receiver for transmission and reception respectively of radio signals between the control computer and the outstation control units.

Ideally, the control computer is hard-wire connected to the radio transmitter and the radio receiver is connected to the mains transmitter modem.

According to another aspect, there is provided a maintenance management system for use with a control computer comprising means for reception of maintenance information including work to be done, time scales, type of work, available resources and processing means for providing maintenance management information based on the maintenance information and the duration of operation of energy-consuming apparatus of a building.

The invention will be more clearly understood from the following description of some preferred embodiments

thereof given by way of example only with reference to the accompanying drawings in which:

Fig. 1 is a general schematic block diagram of an energy management system according to the invention;

Figs. 2 and 3 are schematic block diagrams illustrating two ways of carrying out the invention;

Fig. 4 is a diagrammatic perspective view of a portion of the system; and

Fig. 5 and 6 are block diagrams of various portions of the energy management system.

Referring to the drawings, and initially to Fig. 1 there is illustrated an energy management system according to the invention indicated generally by the reference numeral 1. The system 1 comprises a control computer 2 and a plurality, in this case six, outstation control units 3 accommodated in a relatively large building 4. Each outstation control unit 8 is associated with a particular location for example, a room. Communication means 5 are provided between the control computer 2 and the outstation control units 3. An interface unit 2(a) is connected to the control computer 2 for reception of general energy management information such as North and

South facing exterior temperatures, and a keyboard 2(b) is provided for reception of weather forecast data, building thermodynamic model data and maximal electrical demand information.

Referring now to Fig. 2, one specific arrangement of communication means 5 is illustrated in more detail, and parts similar to those described with reference to Fig. 1 are identified by the same reference numerals. In this embodiment, the control computer 2 is connected to a mains transmitter modem 10 by an RS232 port. The mains transmitter modem 10 transmits frequency shift keyed (FSK) control signals impressed on the mains power supply to the outstations control units 3. These signals are optimised at 300 baud in 220 V A. C. mains wiring. Each outstation control unit 3 includes a mains carrier receiver which picks up the FSK signal and demodulates it back to the original serial data form.

Referring now to Fig. 3 an alternative arrangement of communication means 5 is illustrated and again like parts are assigned the same reference numerals. In this embodiment the control computer 2 is connected to a radio transmitter unit 20 by an RS232 port. The radio transmitter unit 20 comprises a transmitter modem 22 and a transmitter 23 with an antenna 24. At the transmitter unit 20, a combination of audio frequency shift keying

and frequency modulation is used. The communication means 5 further comprises a radio receiver unit 25 having a receiver antenna 26 connected to a receiver unit 27 which, in turn is connected to a modem 28. The modem 28 is connected by an RS232 port to a mains transmitter modem 29 which transmits control signals to the outstation control units 3, again via the mains power supply.

It is envisaged that the communications means may comprise a conventional hard-wire link between the control computer 2 and the outstation control units 3, or alternatively, a direct radio link may be used.

Referring now to Figs. 4 and 5 one of the outstation control units 3 is illustrated in more detail and parts similar to those described with reference to the previous drawings are identified by the same reference numerals. The outstation control units 3 each comprise a real time clock 40, EPROM 41, a microprocessor 43 with a watchdog circuit 43(a), a battery backup 44 for the real time clock, and random access memory (RAM) 45. An analogue RS232 port 46 is provided for connection with building air temperature sensors 47 in this case thermistors and a digital port 48 is provided for connection with an infra-red occupancy detector 49 and for transmitting output signals on lines 5 to control various relays. In this

embodiment, the relays switch lights 50 and a heating radiator 51. A signal conditioning unit 55 is provided for the inputs and outputs. Power is supplied by a power supply unit 42 and control signals, impressed on the mains power supply are read by a communications unit 56.

Needless to say, each outstation control unit may control various other devices, for example, heat pumps, ventilation systems and storage heaters. A light level meter may also be used.

To operate the system, the control computer 2 is loaded with thermodynamic characteristics of the various locations (rooms) of the building. These characteristics include time intervals for temperature projections, heat loss and gain constants for the buildings, and the heat capacity of the walls. This information together with weather forecast data is inputted via the keyboard 2(b). External temperatures are continuously fed in through the interface unit 2(a). All of this information is processed and transmitted in a set of control signals via the communication means 5 to the outstation control units 3.

There are several categories of control signal namely, initalisation, dynamic, system, error control and supervisory commends. Initialisation commands deal with

parameters which are location dependent and do not vary with time. Dynamic commands are the processed information such as temperatures etc and system commands override other commands to control operation of the outstation control units. Error control commands test for abnormal operation of the system and supervisory commends test the communication link. The outstation control units 3 are each located in their associated locations, which in this case are rooms.

The actual time of day and year is loaded in the real time clock 40 of each outstation control unit 3 via a serial port 60. Nominal occupancy hours for the location associated with each outstation control unit 3 are also inputted, for example, 08.30 to 17.00 hours. Two desired air temperatures for each building during occupancy hours are inputted. For example, a level of 18^{o}C may be set for when a room is occupied by at least one person between 08.30 and 17.00 hours and a level of say, 15^{o}C during this time when there is nobody present in the room. Occupancy signals and internal air temperature signals are also received. All of these various constant and variable parameters are used to predict what the building temperature will be at any specified time period later. Using this information, the control unit 3 will decide what controls must be utilised. Further, when a room of a building is unoccupied the lights will be

switched out after a pre-determined time.

In this embodiment, room temperature predictions are calculated by the outstation control units 3 as follows.

Predicted room temp. = Room temp. + Sample time x (Heat supplied + K0occ - Heat lost)/Heat capacity.

OR

$$Ti+1 = Ti + dt/M \times [Crad(Trad-Ti)^{1.25} + Ko0c\sum_{j=1}^{N} 1/Rej(Ti-To)]+/- E$$

where,

Ti+1 = predicted room temperature;

Ti = room temperature;

t = sampling interval;

Trad = radiator temperature;

Ko = occupancy gain;

Oc indicates occupancy;

N = number of external walls;

Re = thermal resistance of wall (ventilation losses included)

To = out temperature, which is a function of outside air temperature and the forecast

temperature;

E = correction constant which is determined from experience;

M = heat capacity; and

Crad = radiator coefficient

The heat lost by the room is given by

$$Qloss = \sum_{j=1}^{N} 1/(R1j+R2jVwj) \times \underline{const}[Tpredicted+KtsTsj+KtnTnj]$$

where,

R1 = resistance of wall, ventilation losses included;

R2 = outer resistance of wall;

Vw = reciprocal of parallel component of wind speed;

Kts,Ktn = constants dependent on orientation of wall and the constant term used in the equation above; and

Tpredicted = forecast outside temperature for that period.

The heat gain to the room is given by:

$$Qgain = Crad(Trad-Ti)^{1.25}$$

Crad is a function of both radiant and conventional heat transfer.

Additional heat gains due to room position and due to ventilation rates may also be accounted for by adding a constant term, say, G.

In this case, maximum electrical demand information from an electrical mains supply demand meter is inputted to the control computer 2 and transmitted to the outstation control units 3. This signal is used to determine which, if any, loads must be disconnected according to how close the electrical demand is to the maximum allowable level.

It will be appreciated that the energy management system of the invention minimises the use of energy-consuming equipment in buildings. This is achieved by monitoring parameters such as room occupancy and external air temperatures in addition to various building heat constants. Accurate calculations of heat loss and residual heat input to a room can be made by taking into account North and South facing wall external temperatures and the weather forecast. For example, if it is predicted that there will be substantial solar gain two hours hence, the system 1 will avoid overheating buildings. By determining room occupancy, the system 1 provides for a much more efficient management of energy-consuming devices as heretofore it is common to have many rooms of very large building complexes continuously heated while they are unoccupied for many hours.

Conventional energy management systems only change desired temperature levels according to "day and night" modes.

It is envisaged that very large cost savings will be made as each outstation control unit 3 incorporates a thermodynamic model of it's associated location (room) 4 and so the system of the invention takes full account of microclimatic conditions. The thermodynamic model may include several models for separate zones within a building, for example, a science laboratory.

The control computer 2 is also programmed to process maintenance information to output maintenance management information including status of work done. In this way, a model of maintenance operation can be created to give a comprehensive planned management programme and to incorporate ad-hoc tasks as and when the need arises.

The maintenance management model is constructed by breaking the overall operation into its basic components such as building work, plumbing work, and electrical work. The resources are defined in the form of employees and contractors and are linked to activities via appropriate command/report structures. The model is then completed by creating a simple list of locations, each with an appropriate reporting structure. This management

programme ties in with the energy management system by taking into account the length of time energy-consuming devices such as lights and boilers are operational. This helps to provide the maintenance management information required.

The monitoring of energy consuming devices may also be used to provide many different types of management information. Fig. 6 illustrates various management information systems loaded in the control computer 2 as follows:-

61 - maintenance control, as described above;

62 - building atlas system which contains details of buildings such as room type;

63 - energy audit system which provides financial information based on usage of energy-consuming equipment;

64 - project control system which helps monitor progress of non-routine jobs;

65 - budget estimating system which ties in with the energy audit system to give budgetary estimates;

66,67 - ordering and stores control systems which indicate maintenance parts inventory; and

68 - wages and salaries system which uses various information, including that generated by the other systems to indicate past, and estimate future outlays.

Therefore, the control computer 2 may produce work lists for individuals and contractors on demand, it records all work done and may refer jobs that cannot be undertaken. It may provide an instantaneous overview of the whole operation together with a wide range of optional reports. Estimated costs may also be assigned to each job, which makes it possible for the programme to automatically audit expenditure on a particular item of plant, for example.

Needless to say the invention is not limited to the specific arrangements illustrated and it is envisaged that the system may be used for controlling many different devices other than those illustrated. For example, the system may be used to set critical temperatures of thermostats using appropriate electro-mechanical interfaces. Further it is envisaged that electrical pumps and air handling units may also be controlled. It is also envisaged that the control unit

of the invention may be wired directly to some or all of the outstation control units.

The invention is not limited to the embodiments hereinbefore described which may be varied in construction and detail.

CLAIMS

1. An energy management system for a building or building complex comprising a control computer, a plurality of outstation control units, each associated with a particular location in the building or building complex, and communication means for communication between the control computer and the outstation control units, wherein the control computer comprises input means for reception of general energy management information including external air temperatures outside both south-facing and north- facing building exterior walls, weather forecast data and building thermodynamic model data, processing means for processing the general energy management information and output means for subsequently transmitting control signals via the communication means to the outstation control units, and in which the outstation control units include means for controlling energy-consuming apparatus in their associated locations in response to the control signals transmitted from the control computer and to energy parameter sensors in their associated locations.

2. An energy management system as claimed in claim 1 in which the input means of the control computer comprises means for reception of maximum electrical demand information and means for processing this information to

provide control signals for transmission to the outstation control units.

3. An energy management system as claimed in claims 1 or 2 in which the control computer further comprises means for reception of maintenance information including work to be done in each location, and the processing means comprises means for providing maintenance management information based on the maintenance information and the duration of operation of energy-consuming devices controlled by the outstation control units.

4. An energy management system as claimed in any preceding claim in which the energy parameter sensors connected to the outstation control units include room occupancy detectors and air temperature sensors.

5. An energy management system as claimed in any preceding claim in which the communication means includes a mains transmitter modem for transmitting control signals impressed on the mains power supply for the outstation control units.

6. An energy management system as claimed in any preceding claim in which the communications means includes a radio transmitter and a radio receiver for transmission and reception respectively of radio signals

between the control computer and the outstation control units.

7. An energy management system as claimed in claim 6 in which the control computer is hard-wire connected to the radio transmitter and the radio receiver is connected to the mains transmitter modem.

8. A building or building complex maintenance management system for use with a control computer comprising means for reception of maintenance information including work to be done, time scales, type of work, available resources and processing means for providing maintenance management information based on the maintenance information and the duration of operation of energy-consuming apparatus of a building.

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